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The Technical Efficiency Analysis – Case of Agricultural Basic Industry in Slovakia

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Abstract

The agricultural companies are operating in the environment with high level of competition and therefore it is for them important to retain respectively to improve their market position to reach higher measure of production process efficiency. As the principal measurement of the production performance was applied technical efficiency which is the assumption to reach the total economical efficiency of company.

According to the results we can state that the technical efficiency measure has during analysed period declining trend. Since the year 2001 when the technical efficiency measure reached the highest level was registered decline of the technical efficiency, except the year 2005. The average level of the technical efficiency measure during the years 2006 and 2007 is possible to explain with increasing differences between the analysed companies. Just few companies achieved very good results in the production process. Based on the results of the technical efficiency measure is possible to expect deepening of differences between the companies in future.

Key words

the Data Envelopment Analysis - DEA, Technical Efficiency, Agricultural Enterprises, Basic Industry

Introduction

Generally is possible to state that objective of the rational owner respectively management is the profit maximization with minimal inputs applying, that means costs. This objective is possible to define as optimizing task which solution could be achieved with applying linear programming methods that means non parametric approach or by econometric methodology – parametric approach. Common sign for both mentioned approaches is production frontier quantification. While parametric approach assume that we know explicit estimation of production function but we do not know its parameters, results of non-parametric approach are estimated measures of technical efficiency which reflect on company's position either on production frontier in case of effective company either under the frontier in case of inefficient company.

We focused research on non-parametric approach application to estimate companies' efficiency which is known as the Data Envelopment Analysis (DEA). The DEA reach good results on small extents of analysed companies and in case of combination with proper statistical tools can answer questions dealing with companies' efficiency.

Theoretical background of technical efficiency analysis set Koopmans, T. C. (1951) who defined technical efficiency as permissible variation input/output vector in which is technically not possible to increase any output (or to reduce any input) without simultaneous reduction of other output or increasing other input. Later Farrell, M. J. (1957) derived input oriented indexes of technical efficiency expressed by radial reduction of all inputs at given level of outputs. These indexes were later inspiration for Charnes, A., Cooper, W. W. and Rhodes, E. (1978), Banker, R. D., Charnes, A. and Cooper, W. W. (1984) a Fähre, R., Grosskopf, S. and Lovell, C. A. K. (1985, 1994) who established the DEA. The DEA is technique which according to the estimation of convex data envelope of analysed producers that means production possibility frontier allowed relative efficiency calculation of all analysed producers. This technique became very popular by technical

efficiency estimation because it allowed with simple method to consider transformation more inputs into more outputs. It is non parametric approach and it does not require input prices and is not needed to define type of producer's behaviour.

Period of lat years is in field of efficiency analysis characterised by new models and methods development as well as with many applications in different branches of economy. With regard on solved issues was major attention paid on empiric applications based on radial and additive models which examine technical efficiency at the companies' level in conditions of the Slovak agriculture. Mentioned approach applied Mathijs, E., Blaas, G. a Doucha, T. (1999) and others.

In issue of the technological level of agricultural production and the level of productivity Smutka, L. et al (2009) emphasized that the character of agricultural sector changed during the last more than 40 years. The number of machines and vehicles increased during the analyzed period by more than 122% and the world agricultural production increased by 148%

There exist many opinions on relation between productivity development (efficiency) and legal forms in transition economies. Petrick, M. a Weingarten, P. (2004) maintain a position that countries in which remain sustentative companies with large area of cultivated land from central planed economy period but which simultaneously adapted organizational structure to new system and optimized number of employees reach higher efficiency measure.

The process of stabilisation and production and productivity growth started in the year 2004 after accession of the new member states into the EU by reduction number employees in agriculture, creation of new institutions and market relations stabilisation (Swinnen, J. M. F. and Vranken, L., 2005).

With aim to prove that private farms are more efficient than cooperatives estimated Mathijs, E. a Vranken, L. (2001) the technical efficiency measure of analysed companies in Bulgaria and Hungary based on the DEA. They stated that there is gradual increase of the technical efficiency of cooperatives which are adapting to the market economy conditions. Private farms reached lower levels of technical efficiency in fields which had higher measure of production uncertainty.

Bielik, P. et al. (2010) stated that no significant differences were occurred between analysed legal forms of Slovak agricultural companies. Any legal form did not reach such tendencies in the TFP index development which will determine it as a dominant group of companies according to the productivity and efficiency long term development. According Čechura, L. (2010) technical inefficiency is a significant phenomenon in Czech agriculture. The average level of technical efficiency is around 90% for Czech agricultural companies.

Thiele, H. a Brodersen, C. (1999) on the basis of the DEA analyzed differences between farm productivity in the east and West Germany. Farms in the West Germany reached higher average technical efficiency measure comparing with the East German farms. The East German farms were characterized by higher variability of the TE what is possible to explain with differences in the managerial skills achieved during the transformation process.

Fast new technologies introduction into the production process is important mainly from the reason of cost reduction per unit of production what with is short-term increasing profit of company which is realizing this process (Hanzell, P. and Haddad, L., 2001). But empirical evidences indicate that the regions or countries which did not utilize production growth possibilities with adopting new technologies are loosing the competitiveness on the global level. On the country level that means that increase of agriculture productivity impact positively decline of foodstuffs prices and that is establishing place for industrial goods and services consumption which will be exhibited by economic growth increase.

Material and methods

The objective of research is the Technical Efficiency estimation of agricultural basic industry subjects in the Slovak Republic during period 1999-2007 and identification of developmental trends. The data were obtained from the Central Database of the Ministry of Agriculture of the Slovak Republic (Information Letters of the MoA SR for the period 1999 – 2007). The base file comprise subjects which object of activity was agricultural

basic industry and file was divided into two sub-files due to different accountancy. In the year 2007 were into sub-file Legal Entities (LE) integrated 1 365 companies, in proportion: 539 agricultural cooperatives (AC), 820 trading companies (TC) and 6 state enterprises. Legal Entities farmed 1 422 360 hectares of agricultural land (average per one company is 1 042 ha of agricultural land, for AC it is 1 363 ha, for TC it is 835 ha, for state enterprises is it 490 ha).

Into sub-file Independently operating farmers (IOF) were included 1 144 farmers which farmed 146 493 ha agricultural land. Average area of cultivated land is 128 ha per one Independently operating farmer.

Into analysed file were included all legal entities and Independently operating farmers which farmed more than 40 ha of agricultural land, declared more than 20 head of cattle or combination of cattle breeding and farming on agricultural land as well as companies farming without land or with small area of land, but in sector of intensive animal breeding.

Independently operating farmers incorporated in analysed data file represented 7.45 % from subjects which received payments in year 2007 (15 532 subjects). Share of legal entities on total quantity of subjects receiving payments in the year 2007 was 8.89 % but they are farming more than three quarters of authorized area for all agricultural subjects in Slovakia.

From the fundamental data file were draw up in the next step by random choice panel data for the period 1999 – 2007 which comprised of 338 legal entities and 83 independently operated farmers so that incorporate proportional representation of subjects farming in all regions in Slovakia, the numerousness of subjects in individual regions was considered also. Analysed data file was redeemed from subjects counting extreme values of variables applied in analysis which will affect total results.

Radial models of the DEA

The technical efficiency is convenient measure to compare production efficiency of group of companies. The advantage of this measure compared partial efficiency indicators is possibility of more input and output application by companies measurement.

Koopmans, T. C. (1951) defined input-output vector technical efficient only in case if increase of any output or decline of any input is possible only by conditions of decline of other output or increase of other input.

Farell, M. J. (1957) developed radial technical efficiency which is comparing vector of concrete firms inputs with production function on which are placed efficient companies. Final value of technical efficiency is in the interval (0,1) and interprets as efficiency of input utilization of concrete company. Firm will be efficient if it reduces inputs by 1 with fixed outputs.

The technical efficiency estimation could be done on the basis of parametric methods of Stochastic Production Functions (SFA) which were presented by Aiger, D., Lovell, C. A. K. and Schmidt, P. (1977) and non-parametric methods of Data Envelope Analysis (DEA) which were worked out by Charnes, A., Cooper, W. W. and Rhodes, E. (1978). The advantage of the DEA comparing with the SFA is independence of functional form of production function. The basis of DEA models is production function estimation with linear programming. Basic DEA model assuming constant returns to scale (DEA CRS) is solving subsequent tasks of mathematical programming

$$\begin{aligned} &min_{\theta,\lambda}\ \theta \\ &-y_i + Y\lambda \geq 0 \\ &\theta x_i + X\lambda \geq 0 \\ &\lambda \geq 0\ , \end{aligned} \qquad (1)$$

where y_i and x_i are values of outputs and inputs, Y and X are matrixes of outputs and inputs, θ scalar a λ vector of constants $N\times 1$.

Subsequently Banker, R. D., Charnes, R. F. and Cooper, W. W. (1984) developed the DEA model which was adjusted to technical efficiency estimation (DEA VRS). With this model was reached possibility to compare companies operating in different areas of return to scale and from this reason was model modified to this equation

$$\begin{aligned} &min_{\theta,\lambda}\ \theta \\ &-y_i + Y\lambda \geq 0 \\ &\theta x_i + X\lambda \geq 0 \\ &N1'\lambda = 1 \\ &\lambda \geq 0\ , \end{aligned} \qquad (2)$$

where y_i and x_i are values of outputs and inputs, Y and X are matrixes of outputs and inputs, θ scalar and λ vector of constants $N \times 1$.

The condition $N1'\lambda = 1$ assigns comparison of companies' efficiency only with those groups of companies which have similar input vector structure.

The result of radial model is simply interpreting because it is summarized in one coefficient which interprets relative company efficiency. Another advantage of radial DEA model is its independence of used measure units. On the other hand the biggest disadvantage is principle of individual input reduction to reach the efficiency.

Relative efficiency of radial DEA model is in the interval <0,1> where the coefficient value 1 means that company is identified as efficient. The difference (1 – coefficient of efficiency) means the value of how much has the company to reduce inputs to be efficient.

Results and discussion

Due to limited monitoring of individual variables in accounting statements of primary producers for technical efficiency estimation according to the fact, that in data file are legal entities and also independently operating farmers, were selected one output – total revenues (incomes) and three inputs - total assets, cultivated land according LPIS and total costs (expenditures). By selecting inputs and outputs were besides of data availability also considered approaches of other authors who examined technical efficiency in group of agricultural companies (Mathijs, E. - Vranken, L., 2001; Swinnen, J. - Vranken, L., 2005).

The development of individual variables which were used in technical efficiency measures as well as its individual components as inputs and outputs is reported in table 1.

Significant changes, which had finally influenced total production efficiency, were recorded in event of total revenues/incomes which as the output were significantly influenced by external factors, mainly weather conditions during individual years of analysed period. Increase of total assets was during the period after accession the Slovak Republic into the EU connected with investment increase which rose during analysed period due to realizing projects co-financed by the EU funds.

During analysed period continued increase of input prices in agriculture mostly due to increase of propellants, feeds, seeds, fertilizers and agents to protect crops. New technologies introduction (in crop production) on the other hand was connected with declining usage of propellants as well as in savings of operating costs. Generally was not obtained significant decrease of operating costs and according to these fact total costs/expenditures increased during whole analysed period.

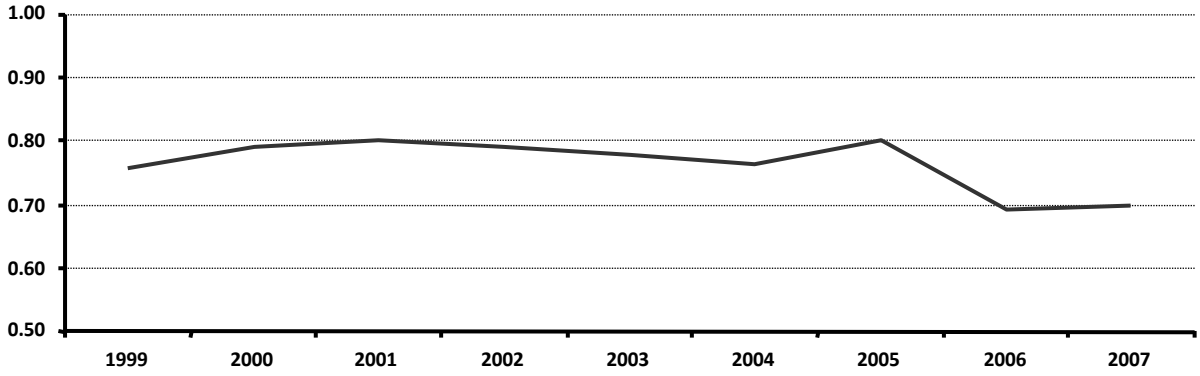
	1999	2000	2001	2002	2003	2004	2005	2006	2007
Revenues (incomes) total in thousands SKK									
Mean value	21 160	22 815	25 206	25 263	23 155	24 718	25 017	26 108	27 211
Maximum	145 050	121 528	131 027	128 108	110 304	111 273	118 902	127 061	132 670
Minimum	179	493	496	562	165	658	14	914	309
Variance coefficient	0.862	0.825	0.829	0.828	0.836	0.830	0.843	0.828	0.816
Total assets in thousands SKK									
Mean value	35 714	34 873	36 279	36 653	34 561	35 522	36 308	35 939	37 223
Maximum	239 863	157 352	178 677	151 445	138 058	134 951	140 422	134 742	159 041
Minimum	140	157	143	343	498	529	6	494	494
Variance coefficient	0.957	0.918	0.903	0.878	0.886	0.863	0.857	0.847	0.830
Farmed land according to the LPIS (farmed land in utilization) in ha									
Mean value	866	875	892	892	891	840	842	829	826
Maximum	3 675	3 675	3 675	3 675	3 425	3 425	3 425	3 425	3 425
Minimum	13	13	25	35	38	39	38	40	27
Variance coefficient	0.631	0.609	0.603	0.600	0.592	0.585	0.574	0.566	0.566
Costs (expenditures) total in thousands SKK									
Mean value	21 546	23 238	24 851	25 147	24 627	24 216	25 048	25 818	26 378
Maximum	143 125	125 444	134 367	123 321	108 695	106 063	110 210	125 053	128 977
Minimum	295	492	535	432	150	655	13	708	393
Variance coefficient	0.855	0.824	0.829	0.825	0.825	0.833	0.834	0.833	0.817

Source: own calculations

Table 1: Descriptive statistics of output and inputs for whole analysed data file during period 1999 – 2007.

The Technical Efficiency Analysis of the Data set

Figure 1 illustrates the technical efficiency measures of analysed data set of companies during the analysed period. According to the results we can state that technical efficiency measure had during analysed period declining trend. Since the year 2001 when the technical efficiency measure reached the highest level (0.802) was registered decline of the technical efficiency, except the year 2005. The average level of the technical efficiency measure during the years 2006 and 2007 is possible to explain with increasing differences between the analysed companies. Just few companies achieved very good results in the production process. Based on the results of the technical efficiency measure is possible to expect deepening of differences between the companies in future.



Source: own calculations

Figure 1: The Technical Efficiency Measure of analysed data set during the period 1999 – 2007.

	1999	2000	2001	2002	2003	2004	2005	2006	2007
Mean value	0.758	0.792	0.802	0.792	0.781	0.764	0.802	0.692	0.700
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Minimum	0.080	0.467	0.553	0.307	0.353	0.312	0.206	0.284	0.282
Variance coefficient	0.192	0.114	0.105	0.122	0.135	0.120	0.113	0.196	0.164

Source: own calculations

Table 2: Descriptive statistics of the Technical Efficiency Measure during period 1999 – 2007.

	1999	2000	2001	2002	2003	2004	2005	2006	2007
0.00 - 0.10	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
0.11 - 0.20	0.24 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
0.21 - 0.30	0.24 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.24 %	0.00 %	0.00 %
0.31 - 0.40	1.19 %	0.00 %	0.00 %	0.24 %	0.00 %	0.24 %	0.00 %	0.48 %	0.48 %
0.41 - 0.50	2.38 %	0.00 %	0.00 %	0.00 %	0.48 %	0.00 %	0.24 %	1.19 %	0.48 %
0.51 - 0.60	4.04 %	0.95 %	0.00 %	0.71 %	1.19 %	0.48 %	0.71 %	14.96 %	6.41 %
0.61 - 0.70	9.74 %	5.70 %	3.80 %	5.23 %	9.50 %	4.28 %	4.04 %	21.38 %	26.13 %
0.71 - 0.80	24.94 %	23.52 %	27.32 %	26.60 %	24.94 %	45.84 %	17.34 %	26.60 %	34.92 %
0.81 - 0.90	28.74 %	43.94 %	39.43 %	38.00 %	37.29 %	32.78 %	51.54 %	23.99 %	21.38 %
0.91 - 0.99	25.89 %	23.52 %	27.08 %	27.32 %	24.94 %	13.78 %	23.28 %	9.03 %	8.55 %
1	2.61 %	2.38 %	2.38 %	1.90 %	1.66 %	2.61 %	2.61 %	2.38 %	1.66 %

Source: own calculations

Table 3: Percentage categorization of the companies into the groups according to the achieved measures of the technical efficiency during period 1999 – 2007.

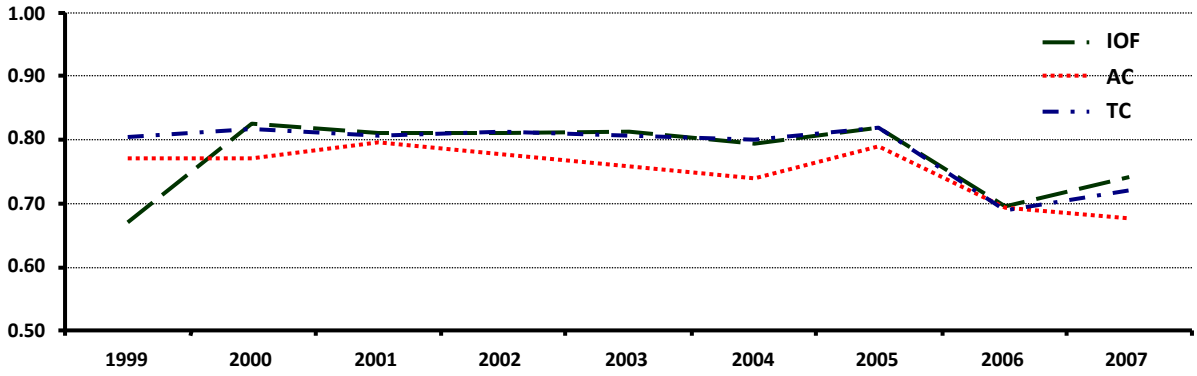
In spite of that the average measure of technical efficiency purvey informational estimation of the total efficiency is appropriate to achieved results verify with companies percentage categorization into the groups according to the achieved measures of the technical efficiency (Table 3).

According to the achieved results is evident that decline of the technical efficiency measure which was confirmed by movements of companies from the groups with higher level of the technical efficiency into the groups with lower level of the measure during the last two years of analysed period.

The Technical Efficiency Analysis of selected groups of companies

With the aim to identify the company type which reached highest measures of the technical efficiency was the analysed data set divided according to the different criterions.

The first criterion was the legal form of the companies. Second criterion was the production orientation. Analysed data set was divided into three groups: group of companies oriented on the crop production, group of companies oriented on the animal breeding and group of companies oriented on the combined production. The distributing criterion was the share of the revenues from the crop production and animal breeding on the total revenues. Into the group of companies oriented on crop production were included companies which reached minimal 75% of total revenues from the crop production. Into the group of companies oriented on animal breeding were included companies which reached minimal 75% of revenues from the animal production. The remained companies were included into the group of combined production.



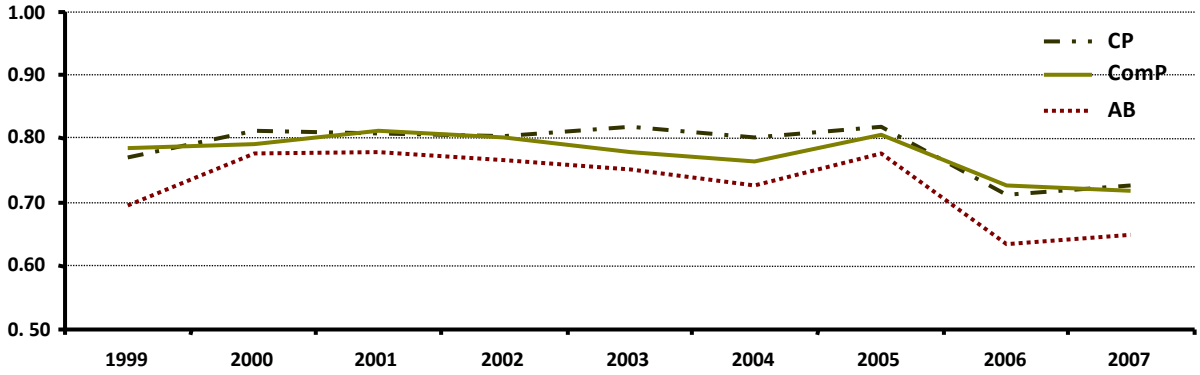
Source: own calculations

Figure 2: The Technical Efficiency Measure in the groups of companies according to the legal form during the period 1999 – 2007.

	1999	2000	2001	2002	2003	2004	2005	2006	2007
P-value	< 0.0001	< 0.0001	0.3256	0.0004	< 0.0001	< 0.0001	0.0012	0.9688	< 0.0001
Significant differences between the groups									
IOF / AC	+	+	-	+	+	+	+	-	+
IOF / TC	+	-	-	-	-	-	-	-	-
AC / TC	-	+	-	+	+	+	+	-	+

Note: (+) significant difference, (-) non-significant difference
Source: own calculations

Table 4: Test of Mean Values of the Technical Efficiency in the groups of companies according to the legal form.



Source: own calculations

Figure 3: The Technical Efficiency Measure in the groups of companies according to the production orientation during the period. 1999 - 2007

Except the years 1999 and 2006 (Figure 2) the trading companies (TC) and Independently operated farmers (IOF) reached higher measures of the technical efficiency.

To verify the statistical differences we applied the test of mean values.

The significant differences of the Technical Efficiency (Table 4) were registered between the Independently Operating Farmers and Agricultural Cooperatives (AC) as well as between the Trading Companies and Agricultural Cooperatives with exception the years 2001 and 2006 when the significant differences were not obtained. Possible reason of this trend is that Agricultural Cooperatives owned Assets not efficiently used and also were characterized with higher debt charge. In comparison the Trading Companies has more balanced structure of assets and the indebtedness was relatively low.

The second criterion was the differentiation according to the production orientation.

According to the presumptions the lowest level of the Technical Efficiency reached companies oriented on the animal breeding (AB). In other hand the most effective were the companies oriented on combined production (ComP).

The significant differences of the technical efficiency were registered during the whole analysed period between the groups of companies oriented on the crop production and on the animal breeding. Except years 2000 and 2003, years characterized with the extremely drought, were recorded also significant differences between the companies oriented on crop production and combined production. This was caused with fact that companies oriented on animal production own high value of assets connected with the animal breeding which consequently caused lower measures of the technical efficiency in comparison with companies oriented on the undemanding crop production with narrow specialization on the cereals and technical crops what is not so significantly assets demanding.

After the accession into the EU was recorded gradual increase of companies oriented exclusively on crop production of main commodities. The companies with combined production finished the breeding of livestock. This trend is connected with companies fitting to the new market conditions and more strict rules of the CAP EU.

Another criterion for technical efficiency estimation of individual groups of companies was the companies' size determined with the cultivated land area and number of employees. Achieved measures of the technical efficiency are illustrated on the figure 4 - 5.

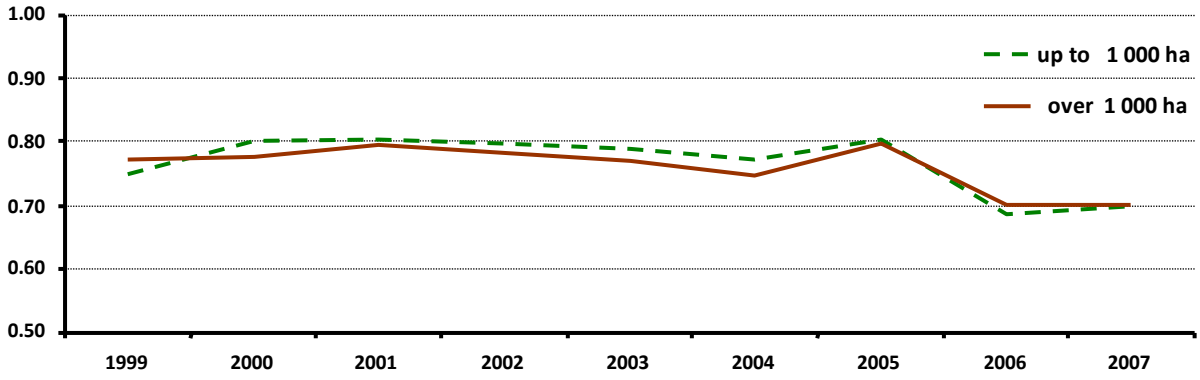
In group of companies with the land area up to 1 000 hectares were predominant the individual operated farmers and companies oriented on the crop production.

The statistical differences in the technical efficiency measures between the groups of companies are specified in table 6.

	1999	2000	2001	2002	2003	2004	2005	2006	2007
P-value	0.0001	0.0071	0.0006	0.0030	0.0001	0.0001	0.0002	0.0001	0.0001
Significant differences between the groups									
CP / ComP	-	-	-	-	+	+	-	-	-
CP / AB	+	+	+	+	+	+	+	+	+
ComP / AB	+	-	+	+	-	+	+	+	+

Note: (+) significant difference, (-) non-significant difference
Source: own calculations

Table 5: Test of Mean Values of the Technical Efficiency in the groups of companies according to the production orientation.



Source: own calculations

Figure 4: The Technical Efficiency Measure in the groups of companies according to the cultivated land area during the period 1999 – 2007.

	1999	2000	2001	2002	2003	2004	2005	2006	2007
P-value	0.0959	0.0056	0.2867	0.0938	0.1308	0.0060	0.5297	0.2107	0.8456
Significant differences between the groups									
up to 1 000 ha / over 1 000 ha	-	+	-	-	-	+	-	-	-

Note: (+) significant difference, (-) non-significant difference
Source: own calculations

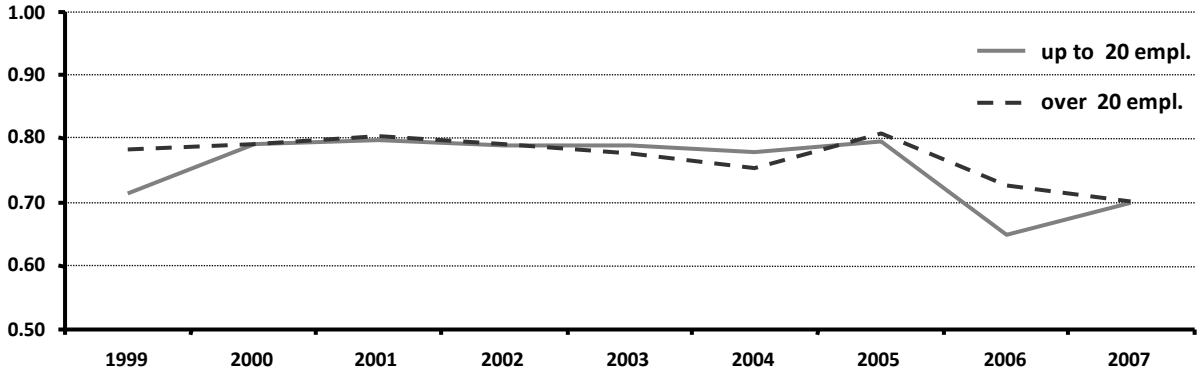
Table 6: Test of Mean Values of the Technical Efficiency in the groups of companies according to the cultivated land area.

During analysed period were reached significant differences in technical efficiency measures just during the years 2000 and 2004 what is possible to explain with minimal crop production due to impact of drought in the year 2000 and 2003. Based on obtained results is not possible to confirm higher measure of technical efficiency of companies with smaller land area.

Except year 2004 (Figure 5) companies with more than 20 employees reached higher measures of technical efficiency what could be connected with higher level of production process efficiency in these companies with higher quality management.

The statistical differences in the technical efficiency measures between the groups of companies are specified in table 7.

During analysed period (Figure 7) were achieved significant differences in technical efficiency in the years 1999, 2004 and 2006 but only in the year 2004 the companies with less than 20 employees reached higher measure of technical efficiency. This fact is possible to explain with considerable impact of poor crop due to drought in the year 2003 what subsequently negatively influenced also the animal breeding in the year 2004.



Source: own calculations

Figure 5: The Technical Efficiency Measure in the groups of companies according to the number of employees during the period 1999 – 2007.

	1999	2000	2001	2002	2003	2004	2005	2006	2007
P-value	< 0.0001	0.8817	0.5019	0.6510	0.2091	0.0056	0.2194	< 0.0001	0.8334
Significant differences between the groups									
up to 20 empl. / over 20 empl.	+	-	-	-	-	+	-	+	-

Note: (+) significant difference, (-) non-significant difference

Source: own calculations

Table 7: Test of Mean Values of the Technical Efficiency in the groups of companies according to the number of employees.

Conclusion

Change of technical efficiency can be interpreted also as relative measure of managerial abilities to exploit inputs in given technological conditions.

The most stabile development was reached in case of total productivity change which except years 2003 and 2005 reached in comparing with previous periods positive increase. Years 2003 and 2005 were characteristic by not favourable weather and climate conditions which in resort of agriculture negatively affected the significant decline of production. Finally we can state that in spite of not favourable conditions in separate period total productivity during analysed period increased. The development of the average measures of the Technical Efficiency of the companies reached moderate decline after the accession into the EU, what is probably the consequence of the increasing investing activity. The average measure of the Technical Efficiency is possible to explain with increasing differences between the companies in analysed data set.

From the reason of more detailed analysis were companies divided into groups according to the specific criterions. Based on the results is clear that between some of analysed groups are significant differences.

The production orientation was confirmed as the significant factor influencing the total efficiency. Companies oriented on animal breeding reached the lowest level of technical efficiency in comparison with companies oriented on crop production and combined production. This fact confirm current situation in the animal production which is characterized with decline of total production and gradual decline of prices.

As the main reason of inefficiency in analysed data set was identified input of assets. The highest measure of inefficiency was obtained in group of companies oriented on animal breeding. This fact confirmed also the hypothesis of not efficient assets exploitation of animal breeding companies.

According to the Technical Efficiency development we expect that the differences will deepen in future period.

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